PB85-169621

Development of a Guidance Manual for the Selection and Use of Sorbents for Liquid Hazardous Substance Releases

JRB Associates, Inc., McLean, VA

Prepared for

Environmental Protection Agency, Cincinnati, OH

Feb 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-169621

EPA/600/D-85/015
February 1985

DEVELOPMENT OF A GUIDANCE MANUAL FOR THE SELECTION AND USE OF SORBENTS FOR LIQUID HAZARDOUS SUBSTANCE RELEASES

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EPA Contract
68-03-3113

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REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-85/015	2.
3. RECIPIENT'S ACCESSION NO. PB85 169621/AS	
4. TITLE AND SUBTITLE: DEVELOPMENT OF A GUIDANCE MANUAL FOR THE SELECTION AND USE OF SORBENTS FOR LIQUID HAZARDOUS SUBSTANCE RELEASES	5. REPORT DATE: February 1985
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): R. Melvold, S. Gibson, R. Scarberry, W. Ellis, M. Royer	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: JRB Associates, 8400 Westpark Drive, McLean, VA 22102	10. PROGRAM ELEMENT NO. CRB1DA
	11. CONTRACT/GRANT NO. 68-03-3113
12. SPONSORING AGENCY NAME AND ADDRESS: Hazardous Waste Engineering Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH 45268	13. TYPE OF REPORT AND PERIOD COVERED: Conference Paper
	14. SPONSORING AGENCY CODE: EPA/600/12

15. SUPPLEMENTARY NOTES: Micheal D. Royer, P.O. Releases Control Branch, Hazardous Waste Engineering Research Laboratory, Edison, NJ 08837 FTS 340-6633

16. ABSTRACT

This study was conducted to provide information for the selection and use of sorbents for cleanup or control of liquid hazardous substances. Literature reviews, sorbent manufacturer data and experiences of On-Scene Coordinators were reviewed in conjunction with laboratory studies. These laboratory studies determined the compatibility and sorption capacity of selected representative hazardous liquid-sorbent pairs. The combined experimental and literature data are being used to prepare A Guidance Manual for the Selection and Use of Sorbents for Hazardous Substance Releases. On-Scene Coordinators and their technical support personnel are the primary target audience for the Manual.

To utilize the Manual, the user must first identify the spilled liquid. If it is one of the 200+ liquid hazardous substances addressed in the Manual, a reference is provided to one of 25 "Sorbent Selection and Use Guides". Each of the "Guides" enables the user to rapidly identify generic sorbent classes, physical forms, and methods for application and collection that are most suitable for each of four different chemical release-control scenarios: 1) a spill onto land; 2) a floating release into water; 3) a non-floating release into water; and 4) immobilization for landfilling. The Manual contains "Sorbent Data Sheets" for 13 generic classes of sorbents other than activated carbon. These data sheets contain information on manufacturers, acquisition costs, bulk density and sorbent limitations. The sorption capacity of 190 sorbent-chemical pairs was determined and recorded in the Manual. The Manual also includes cost and estimation procedures, test methods, hazardous liquid physical properties, and a description of the rationale for the release-control scenarios.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT: RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)*: UNCLASSIFIED	21. NO. OF PAGES: 19
	20. SECURITY CLASS *(This page)*: UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

DEVELOPMENT OF A GUIDANCE MANUAL FOR THE SELECTION AND USE OF SORBENTS FOR LIQUID HAZARDOUS SUBSTANCE RELEASES

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This study was conducted to provide information for the selection and use of sorbents for cleanup or control of liquid hazardous substances. Literature reviews, sorbent manufacturer data and experiences of on-scene coordinators were reviewed in conjunction with laboratory studies. These laboratory studies determined the compatibility and sorption capacity of selected representative hazardous liquid-sorbent pairs. The combined experimental and literature data are being used to prepare A Guidance Manual for the Selection and Use of Sorbents for Hazardous Substance Releases. On-Scene Coordinators and their technical support personnel are the primary target audience for the manual.

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The Manual contains "Sorbent Data Sheets" for 13 generic classes of sorbents other than activated carbon. These data sheets contain information on manufacturers, acquisition costs, bulk density and sorbent limitations. The sorption capacity of 190 sorbent-chemical pairs were determined and recorded in the Manual. The Manual also includes cost and estimation procedures, test methods, hazardous liquid physical properties, and a description of the rationale for the release-control scenarios.

INTRODUCTION

Spills and uncontrolled releases of liquid hazardous substances pose a severe threat to the public and the environment. These substances may be released at fixed sites or during transportation accidents and generally require control and cleanup. Sorbents are potentially effective materials for cleaning up and controlling many releases of liquid hazardous substances. The Manual described in this article is designed to facilitate the selection and use of appropriate sorbents for treating releases of hazardous liquids. The Manual is targeted primarily to assist Federal On-Scene Coordinators (OSC's) and their technical support staffs, but is also applicable to emergency response, spill cleanup and industrial personnel who respond to releases of hazardous liquids and immobilize such substances prior to disposal.

Development of the Manual involved a review of the literature, sorbent manufacturers' data, OSC experiences, and laboratory studies. The laboratory studies determined the compatibility and sorption capacity of selected hazardous liquid-sorbent pairs. To establish a framework for the Manual, four liquid release-control scenarios were studied: 1) a spill onto land;

2) a floating release onto water; 3) a non-floating release into water; and 4) immobilization for landfilling. "Sorbent Selection and Use Guides" were developed which list sorbents for each release-control scenario. Sorbent Data Sheets were also prepared for each of 13 classes of sorbents. The Manual also provides information on sorbent application, collection and disposal, cost estimation procedures, test methods, hazardous liquid physical properties, and a narrative to enable selection of appropriate sorbents. The Manual is designed to provide information for rapid decision making and for conducting thorough evaluations of alternative sorbent-use strategies.

PROCEDURES

The Manual development project was completed in three phases. The approach and results of each phase are described below.

Phase 1: Information Collection and Test Plan Development

Development of a List of Applicable Hazardous Liquids

A list of hazardous liquids for which the Manual would be applicable was developed from the substances regulated by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, PL96-150 (CERCLA). The CERCLA hazardous liquids of concern are 213 neat hazardous substances that meet the liquid criteria designation (i.e., that a substance possess a melting point at or below 77°F (25°C) and a boiling point at or above 50°F (10°C)). Waste mixtures were not considered.

These CERCLA-regulated liquid hazardous substances were placed into 27 classes according to functional groups (Herrick et al, 1982). Since it was

not possible to experimentally evaluate all of the CERCLA hazardous liquids, representative hazardous liquids were selected from each chemical class based on aqueous solubility, specific gravity, liquid surface tension, and viscosity. Table 1 lists the chemical classes and guide numbers to which each hazardous liquid was assigned.

Table 1. CERCLA Liquid Chemical Classes

Chemical Class	Guide #	Chemical Class	Guide #
Acidic compounds, inorganic	1	Esters and ethers	15
Acidic compounds, organic	2	Ethers, halogenated	16
Alcohols and glycols	3	Halides, inorganic	17
Aldehydes	4	Heavy metals	18
Aliphatic hydrocarbons	5	Hydrazines and hydrazides	19
Aliphatics, halogenated	6	Ketones	20
Amides, anilides, and imides	7	Nitro/nitroso compounds	21
Amines, alkyl	8	Organophosphates	22
Amines, aryl	9	Oxides, alkylene	23
Aromatic hydrocarbons	10	Peroxides	24
Aromatics, halogenated	11	Phenols and cresols	25
Basic compounds	12	Sulfates and sulfites	26
Cyanates and isocyanates	13	Sulfides and mercaptans	27
Cyanides and nitriles	14		

Collection of Information

To complete the "Sorbent Selection and Use Guides" and the "Sorbent Data Sheets," pertinent data were collected. The physical data gathered for each liquid included specific gravity, aqueous solubility, surface tension, and viscosity. For physical data that was unavailable from technical reference materials and journals, the data were solicited from chemical manufacturers of the liquids.

A literature review was also conducted to identify available sorbents and their manufacturers, and to obtain published data on sorbent properties and performance. Based on information deficiencies noted in the available literature,

data sheets were requested from sorbent producers. Limited sorbent property and procurement information, and sorbent-hazardous liquid pair data such as sorption capacity, retention capacity, sorbent compaction and expansion data, performance parameters and safety precautions were obtained.

Test Plan Formation

For each chemical class, a representative chemical was chosen. Similarly, a representative sorbent was chosen from each of the 13 generic sorbent classes. Those representative sorbent-hazardous liquid pairs for which no data were available became primary candidates for testing. The selection of a hazardous liquid for testing considered the probability that a substance from one of the 27 chemical classes would be released and the degree of hazard that it would present to public health or the environment. Probability of a release was based on the annual production volume, while the degree of hazard was based on the proposed reportable quantity (RQ) of the CERCLA liquid as promulgated by the Environmental Protection Agency in 48FR23552-23605 and subsequent revisions. The sorbents were assigned a priority for testing based on 1) sorbent availability and 2) sorbent applicability for ameliorating a spill similar to one or more of the four cleanup scenarios. The following list presents the 13 generic sorbent categories identified by the project:

Sorbent Clay
Diatomite
Wood Fiber
Treated Wood Fiber
Expanded Mineral
Foamed Glass
Polyurethane
Polyethylene
Polypropylene
Cross-Linked Polymer
Feathers
Treated Clay/Treated Natural Organic
Treated Expanded Mineral/Treated Wood Fiber

The sorbent-hazardous liquid pairs chosen for testing were from the top priority groups, resulting in selection of a maximum of 250 pairs from 23 chemical classes and 10 generic sorbents.

PHASE 2: Compatibility and Sorption Capacity Testing

Laboratory experiments and estimation procedures were employed in Phase 2 to generate or estimate sorbent performance data that were not available from the literature. The Phase 2 work included:

Compatibility Testing

A Standard Operating Procedure (SOP) was prepared that describes the procedures employed in conducting the compatibility tests. When a gross incompatibility was observed or degradation of the sorbent occurred, the sorbent-hazardous liquid pair was excluded from sorption capacity testing. Also, when the sorbent was not wetted by the hazardous liquid, the sorbent-liquid pair did not qualify for sorption capacity testing. The sorption capacity measurements of 190 sorbent-liquid pairs were conducted in Phase 2 of the project. The 10 sorbents tested for sorption capacity with the representative hazardous liquids were also tested for their sorption capacity with water. The data obtained were used in determining hazardous liquid/water preference indices for the sorbents.

Sorption Capacity Testing

The sorbent testing protocol consists of three procedures for three different sorbent forms: (1) A decanting procedure for particulate sorbents, in which after a 2-hour exposure in a graduated cylinder, the hazardous liquid is poured out through a stainless steel screen leaving behind the loaded sorbent for measurement; (2) A volume measurement procedure for finely-divided particulate

sorbents, wherein the sorbent is allowed to settle and the volume of the sorbent layer (and the liquid contained therein) is determined; and (3) A pad/mat immersion procedure, in which a standard-sized sorbent specimen is immersed in and then removed from a hazardous liquid and weighed after dripping ceases.

Sorbent/Hazardous Liquid Data Estimation

Project funds did not permit experimental determination of all sorbent-hazardous liquid sorption capacity values of interest. Procedures were established for estimating sorption capacities for cases where the untested sorbent-chemical pair was sufficiently similar to pairs for which data were available. The estimation procedures are not rigorously defensible from a scientific standpoint, but it was concluded that On-Scene Coordinators and their technical support personnel would be forced to develop similar estimation procedures when faced with hazardous liquid releases for which sorption capacity data did not exist. Therefore, the estimates were made, included in the Manual, and clearly marked as estimates.

Phase 3: Manual Preparation

This phase of the project involved the following activities:

° Development of the "Sorbent Selection and Use Guides"

° Preparation of the "Sorbent Data Sheets"

° Production of ancillary data tables:

- sorption capacity
- hazardous liquid/water preference
- physical properties
- test methods
- equipment/sorbent costs

° Preparation of the handbook text

Description of these elements follows in the Results and Discussion section.

RESULTS AND DISCUSSION

A draft document, A Guidance Manual for the Selection and Use of Sorbents for Liquid Hazardous Substance Releases has been prepared, which contains eight sections. The first three sections, "Sorbent Selection and Use", "Sorbent Data", and "Technical/Logistical Information", are essential to users who require a condensed source of sorbent selection and use guidance. The other five sections, "Cost Estimation Procedures and Data", "Test Methods", "Spill Scenario Rationale", "Sources of Information", and "CERCLA Liquid Chemical Information," explain the rationale used to develop the condensed guidance in the first three sections and also provide information that enables the user to acquire and use sorbent information for specific needs. A synopsis of each of the eight sections is provided below.

Section A - "Sorbent Selection and Use"

Two CERCLA Liquids Indexing Tables are an integral part of Section A. The first indexing table lists CERCLA designated hazardous liquids, the chemical class and guide number to which each liquid has been assigned, the CAS number for each liquid, the hazards in addition to toxicity, and the behavior of the liquid in water. The second indexing table lists the 4-digit DOT ID number used in commercial shipping, and supplemental information similar to that in the first indexing table. Information is provided for all 213 CERCLA liquids that were identified.

Section A of the guide also contains the "Sorbent Selection and Use Guides". Each "Guide" presents information on the use of sorbents relevant to the four scenarios: Landspill, Floating Spill, Non-Floating Spill, and Landfill. Chemical functional classes are generally regarded to be descriptive of the

chemical reactivity of the CERCLA liquids; consequently, one guide was prepared for each chemical class for which data were available. Each guide lists generic sorbents, in recommended order for consideration for each of the four scenarios An example of a "Sorbent Selection and Use Guide" is in Table 2. Application and collection procedures are listed in each "Guide" based on assessment of the optimal procedures for use with each generic sorbent. For each sorbent listed in each "Guide", the page number of the "Sorbent Data Sheet" is also included.

Section B - "Sorbent Data"

This section contains 1) an index of sorbent manufacturers, trade names, and generic sorbent categories, 2) 13 "Sorbent Data Sheets", 3) the sorption capacity data, and 4) the hazardous liquid/water preference indices.

A "Sorbent Data Sheet" was prepared for each generic class of sorbents. Each data sheet lists the generic sorbent class, commercial trade-names, manufacturers data on the types of sorbents, their cost, bulk density and storage requirements. The sorbent types generally available include: particulates, pillows, pads, mats, and booms. The data sheets also report limitations on the use of each generic sorbent for landspills, floating spills and non-floating spills. Hazards relative to gross incompatibilities, health, safety, and environmental concerns are delineated and the sorbent density is also given. The format allows for updating of the Sorbent Data Sheets as additional sorbents become available. An example of a Sorbent Data Sheet is shown in Table 3. Sorption capacity data for the representative sorbent-hazardous liquid pairs are also tabled in Section B (Table 4). Another table in Section B (Table 5) contains hazardous liquid-water preference indices, which are the the grams of hazardous liquid sorbed to the grams of water sorbed by the same quantity of

SORBENT SELECTION AND USE GUIDE

GUIDE NUMBER 10

CHEMICAL CLASS: Aromatic Hydrocarbons

REPRESENTATIVE HAZARDOUS LIQUID: Toluene

For releases onto land, recommended sorbents are listed in prioritized order under the Landspill Scenario, for water, under the Floating Spill or Non-Floating Spill Scenarios, and, for landfill applications, under Landfill Scenario. For additional sorbent prioritization information, see the Sorbent Prioritization tables on pages I-2 thru I-7, Section I of the handbook. Also, for additional sorbent specifics turn to the Sorbent Data Sheet found on the page listed in the prioritized sorbent column. Pertinent logistical information, such as application and collection methodology, is given in Section C of the handbook.

LANDSPILL - SMALL

Prioritized Sorbents/Type/Pg	Application	Collection	Limitations
(1)Feathers/pl/B-12	Throw	Pitchfork	DGC,RT
(2)CLP/p/B-11	Shovel	Shovel	R,W,SS
(2)CLP/pl/B-11	Throw	Pitchfork	R,DGC,RT
(3)Sorbent Clay/p/B-2	Shovel	Shovel	R,I,P
(3)TC/p/B-13	Shovel	Shovel	R,I
(4)Wood Fiber/pl/B-4	Throw	Pitchfork	R,P,DGC,RT

LANDSPILL - MEDIUM

Prioritized Sorbents/Type/Pg	Application	Collection	Limitations
(1)CLP/p/B-11	Blower	Skiploader	R/W/SS
(2)TC/p/B-13	Blower	Skiploader	R/I
(3)Sorbent Clay/p/B-2	Blower	Skiploader	R,I,P
(3)Polypropylene/p/B-10	Blower	Skiploader	W,SS,DGC
(3)Feathers/pl/B-12	Throw	Skiploader	DGG,RT
(4)Ex Mineral/p/B-6	Blower	Skiploader	R,I,W,P,DGC

FLOATING SPILL

NON-FLOWING - SMALL POND

Prioritized Sorbents/Type/Pg	Application	Collection	Limitations
(1)CLP/pl/B-11	Throw	Spear	R
(2)Feathers/pl/B-12	Throw	Spear	
(2)TW Fiber/pl/B-5	Throw	Spear	
(3)Polyurethane/m/B-8	Throw	Spear	
(4)Polypropylene/m/B-10	Throw	Spear	
(4)Polyethylene/m/B-9	Throw	Spear	

NON-FLOWING - LARGE LAKE

Prioritized Sorbents/Type/Pg	Application	Collection	Limitations
(1)CLP/pl/B-11	Boat/Throw	Boat/Spear	R
(2)Feathers/pl/B-12	Boat/Throw	Boat/Spear	
(3)TW Fiber/pl/B-5	Boat/Throw	Boat/Spear	
(4)Polypropylene/m/B-10	Boat/Throw	Boat/Spear	
(4)Polyurethane/m/B-8	Boat/Throw	Boat/Spear	
(5)Polyethylene/m/B-9	Boat/Throw	Boat/Spear	

FLOWING - SMALL CREEK

Prioritized Sorbents/Type/Pg	Application	Collection	Limitations
(1)Polypropylene/b/B-10	Hand	Hand	
(2)Polyurethane/b/B-8	Hand	Hand	
(3)Feathers/b/B-12	Hand	Hand	
(4)TW Fiber/b/B-5	Hand	Hand	
( )			
( )			

FLOWING - LARGE RIVER

Prioritized Sorbents/Type/Pg	Application	Collection	Limitations
(1)Polyproplene/b/B-10	Boat/Hand	Boat/Winch	
(2)Polyurethane/b/B-8	Boat/Hand	Boat/Winch	
(3)Feathers/b/B-12	Baot/Hand	Boat/Winch	
(4)TW Fiber/b/B-5	Boat/Hand	Boat/Winch	
( )			
( )			

NON-FLOATING SPILL

COLUMN TREATMENT

Prioritized Sorbents/Type/Pg	Limitations
(1)Polypropylene/p/B-10	R,I
(2)TC/p/B-13	
( )	
( )	
( )	
( )	

BATCH TREATMENT

Prioritized Sorbents/Type/Pg	Limitations
(1)Feathers/pl/B-12	R
(1)Polyethylene/m/B-9	
(1)Polyurethane/m/B-8	
(1)CLP/pl/B-11	
(2)Polypropylene/m/B-10	
(3)CLP/p/B-11	R,RH

LANDFILL

Prioritized Sorbents/Type/Pg	Estimated* Disposal Costs($)
(1)Ex Mineral/p/B-6	1175
(2)TC/p/B-13	1358
(3)Sorbent Clay/p/B-2	1674
(4)Wood Fiber/p/B-4	2017
(5)Foamed Glass/p/B-7	3271
(6)Polypropylene/p/B-10	3852

* Cost includes sorbent, drums, mixing, transportation, and disposal associated with landfill of 1000 gals. of hazardous liquid.

Legend:

b	= Boom	pl	= Pillow
CLP	= Cross linked polymer	R	= Not reusable
DGC	= Not effective where ground cover is dense	RH	= Removability (from batch contactor) is difficult
Ex Mineral	= Expanded mineral	RT	= Not effective where terrain is rugged
I	= Not incinerable	SS	= Not for use within environmentally sensitive sites
m	= Mat	TC	= Treated clay/treated natural organic
p	= Particulate	TW Fiber	= Treated wood fiber
P	= Effectiveness reduced when rainy	W	= Effectiveness reduced when windy

TABLE 2 Sorbent Selection and Use Guide example

SORBENT DATA SHEET

GENERIC CLASS: Sorbent Clay

SND-G, SNG-M o Oil Dry Corporation Chicago, IL 312-321-1515 o Cost: Particulate - $0.05/lb o Bulk Density: 29-36 lb/ft^3 o Store: Dry	Clean Dri, Quick Sorb, Absorbs-It Clean Up 1 o Excel-Mineral Co. Goleta, CA 805-683-5321 o Cost: Particulate - $0.12/lb o Bulk Density: 34-38 lb/ft^3 o Store: Dry	Safestep, Friction o Andesite of California, Inc o Cost: Particulate - $0.49/lb o Bulk Density: 37 lb/ft^3 o Store: Dry
Lowe's Safety Absorbent o Lowe's, Inc. South Ben, In 219-234-8191 o Cost: Particulate $0.04/lb o Bulk Density: 42 lb/ft^3 o Store: Dry	Waverly o Waverly Mineral Products Co. Bala Cynwyd, PA 215-668-2808 o Cost: particulate - $1.50 o Bulk Density: 30-40 lb/ft^3 o Store: Dry	

NOTE: Sorbent Clays are commercially available as kitty litter

LIMITATIONS

Landspill
Not reusable or incinerable, effectiveness reduced when rainy

Floating Spill - Non-Flowing Mode
Not for use on spills into water

Floating Spill - Flowing Mode
Not for use on spills into water

Non-Floating Spill
Not for use on spills into water

INCOMPATIBILITIES

- Acidic compounds, inorganic
- Halides, inorganic
- Cyanates and isocyanates
- Heavy metals

HEALTH/SAFETY CONSIDERATIONS
Wear dust respirator and eye protection when handling particulate and other protective equipment appropriate for the hazardous liquid.

ENVIRONMENTAL CONSIDERATIONS
Does not biodegrade, but is a natural component of the environment.

SORBENT DENSITY
137.2 pounds/cubic foot

PERFORMANCE

Sorption capacity data and hazardous liquid/water preference index information are given in Tables B1 and B2, respectively. If the sorbent/hazardous liquid pair is either observed or known to be incompatible, an "I" is given in the Table B1, or if the sorbent is not wetted by the hazardous liquid, an "NW" is used.

TABLE 3. Sorbent Data Sheet example

TABLE 4 SORPTION CAPACITIES OF REPRESENTATIVE SORBENT/HAZARDOUS LIQUID PAIRS*

Chemical Class	Guide No.	Representative Hazardous Liquid	GENERIC SORBENT CLASS											
			SC	D	WF	TWF	EM	FG	PU	PE	PP	CLP	F	TC
Acidic compounds, inorganic	1	Nitric acid	I	I	I	I	7.1	[15.2]	I	I	NW	I	ND	ND
Acidic compounds, organic	2	Acrylic acid	1.3	1.4	2.0	2.0	4.8	11.6	I	13.0	9.0	5.9	ND	ND
Alcohols & glycols	3	Allyl alcohol	1.0	1.2	1.4	1.7	4.0	9.3	12.3	12.0	7.9	3.3	ND	ND
Aldehydes	4	Furfural	1.2	1.7	2.3	1.7	5.4	11.5	18.1	12.8	11.0	4.3	ND	ND
Aliphatic hydrocarbons	5	Isoprene	0.7	1.1	1.2	1.2	3.5	7.7	7.3	12.0	6.5	16.3	ND	ND
Aliphatics, halogenated	6	Trichloroethylene	1.6	2.5	2.4	2.2	6.7	12.1	20.4	25.6	11.3	36.9	ND	ND
Amides, anilides, & imides	7	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Amines, alkyl	8	Triethylamine	0.8	1.0	0.8	1.3	3.0	[8.6]	8.7	12.2	7.1	14.0	ND	ND
Amines, aryl	9	Pyridine	(1)	(2)	(2)	(2)	(5)	(11)	(18)	(21)	(11)	ND	ND	ND
Aromatic hydrocarbons	10	Toluene	[0.8]	2.1	1.6	1.4	4.5	[9.2]	12.6	17.6	8.3	18.3	[6.1]	[21.6]
Aromatics, halogenated	11	o-Dichlorobenzene	1.5	2.3	2.4	2.0	5.2	11.8	19.2	22.3	11.2	29.6	ND	ND
Basic compounds	12	Ammonium hydroxide	1.0	I	I	I	4.1	13.3	NW	NW	NW	3.8	ND	ND
Cyanates & isocyanates	13	Toluene diisocyanate	I	I	2.6	2.1	5.2	[14]	15.3	21.0	10.7	5.3	ND	ND
Cyanides & nitriles	14	Acetonitrile	0.9	1.1	1.6	1.4	3.8	10.5	NW	10.0	8.6	2.7	ND	ND
Esters & ethers	15	1,4-Dioxane	1.1	1.4	2.3	1.8	5.4	12.6	14.9	14.6	9.5	10.5	ND	ND
Ethers, halogenated	16	2-Chloroethyl vinyl ether	(1.1)	(1.4)	(2.3)	(1.8)	(5.4)	(12.6)	(14.9)	(14.6)	(9.5)	(10.5)	ND	ND
Halides, inorganic	17	Phosphorus trichloride	I	I	2.4	I	8.1	[14.4]	18.8	26.3	11.1	41.6	ND	ND
Heavy metals	18	Lead fluoborate	I	I	4.0	NW	I	I	NW	NW	NW	10.5	ND	ND
Hydrazines & hydrazides	19	Methyl hydrazine	0.9	1.1	I	I	I	I	I	8.5	7.7	3.2	ND	ND
Ketones	20	Methyl isobutyl ketone	1.0	1.2	1.4	1.3	3.8	6.7	9.0	10.7	6.5	12.7	ND	ND
Nitro/nitroso compounds	21	Nitrobenzene	(1)	(1)	(2)	(2)	(5)	(12)	(14)	(13)	(10)	ND	ND	ND
Organophosphates	22	Malathion	1.3	1.5	2.2	1.9	4.4	10.5	12.6	16.8	8.9	7.3	ND	ND
Oxides, alkylene	23	Propylene oxide	0.8	1.1	1.4	1.1	3.8	8.9	12.4	12.2	7.9	11.4	ND	ND
Peroxides	24	alpha,alpha-Dimethyl-benzylhydroperoxide	1.1	1.5	2.6	1.7	4.8	12.5	25.1	15.8	9.3	3.9	ND	ND
Phenols & cresols	25	Cresol	1.3	1.5	2.6	2.0	4.9	12.0	I	17.2	10.0	13.9	ND	ND
Sulfates & sulfites	26	Dimethyl sulfate	1.3	2.0	2.1	2.3	5.9	13.1	15.5	14.6	11.2	5.2	ND	ND
Sulfides & mercaptans	27	Carbon disulfide	1.3	2.0	2.7	1.9	5.5	[12.6]	14.4	13.1	11.9	30.2	ND	ND
Water			1.0	1.4	3.3	1.0	5.5	12.9	2.4	1.4	0.1	2.5	ND	ND

* The reported sorption capacity data are given in grams of hazardous liquid per gram of sorbent and were measured experimentally in the laboratory except as noted:
( ) = estimated value
[ ] = literature value

LEGEND:

CLP = Cross-Linked Polymer
D = Diatomite
EM = Expanded Mineral
F = Feathers
FG = Foamed Glass
I = Incompatible
ND = No Data
NW = Non-Wetting
PE = Polyethylene
PP = Polypropylene
PU = Polyurethane
SC = Sorbent Clay
TC = Treated Clay/Treated Natural Organic
TWF = Treated Wood Fiber
WF = Wood Fiber

TABLE 5 REPRESENTATIVE HAZARDOUS LIQUID/WATER PREFERENCE INDICES*

Chemical Class	Guide No.	Representative Hazardous Liquid	GENERIC SORBENT CLASS								
			SC	D	WF	TWF	EM	FC	PU	PE	PP	CLP
Acidic compounds, inorganic	1	Nitric acid	**	**	**	**	1.3	[1.2]	**	**	**	**
Acidic compounds, organic	2	Acrylic acid	1.3	1.0	0.6	2.0	0.9	0.9	**	9.3	90.0	2.4
Alcohols & glycols	3	Allyl alcohol	1.0	0.9	0.4	1.7	0.7	0.7	5.1	8.6	79.0	1.3
Aldehydes	4	Furfural	1.2	1.2	0.7	1.7	1.0	0.9	7.5	9.1	110.0	1.7
Aliphatic hydrocarbons	5	Isoprene	0.7	0.8	0.4	1.2	0.6	0.6	3.0	8.6	65.0	6.5
Aliphatics, halogenated	6	Trichloroethylene	1.6	1.8	0.7	2.2	1.2	0.9	8.5	18.3	113.0	14.8
Amides, anilides, & imides	7	**	**	**	**	**	**	**	**	**	**	**
Amines, alkyl	8	Triethylamine	0.8	0.7	0.2	1.3	0.6	[0.7]	3.6	8.7	71.0	5.6
Amines, aryl	9	Pyridine	(1.0)	(1.4)	(0.6)	(2.0)	(0.9)	(0.9)	(7.5)	(15.0)	(110.0)	**
Aromatic hydrocarbons	10	Toluene	[0.8]	1.5	0.5	1.4	0.8	[0.7]	5.3	(12.6)	83.0	7.3
Aromatics, halogenated	11	o-Dichlorobenzene	1.5	1.6	0.7	2.0	1.0	0.9	8.0	15.9	112.0	11.8
Basic compounds	12	Ammonium hydroxide	1.0	**	**	**	0.8	1.0	**	**	**	1.5
[illegible] & [illegible]	13	Toluene diisocyanate	**	**	0.8	2.1	1.0	[1.1]	6.4	15.0	107.0	2.1
Cyanide nitriles	[illegible]	Acetonitrile	0.9	0.8	0.5	1.4	0.7	0.8	**	7.1	86.0	1.1
Esters & ethers	15	1,4-Dioxane	1.1	1.0	0.7	1.8	1.0	1.0	6.2	10.4	95.0	4.2
Ethers, halogenated	16	2-Chloroethyl vinyl ether	1.1	1.0	0.7	1.8	1.0	1.0	6.2	10.4	95.0	**
Halides, inorganic	17	Phosphorus trichloride	**	**	0.7	**	1.5	[1.1]	7.9	18.8	111.0	16.6
Heavy metals	18	Lead fluoborate	**	**	1.2	**	**	**	**	**	**	4.2
Hydrazines & hydrazides	19	Methyl hydrazine	0.9	0.8	**	**	**	**	**	6.1	77.0	1.3
Ketones	20	Methyl isobutyl ketone	1.0	0.9	0.4	1.3	0.7	0.5	3.8	7.6	65.0	5.1
Nitro/nitroso compounds	21	Nitrobenzene	(1.0)	(0.7)	(0.6)	(2.0)	(1.0)	(1.0)	(5.8)	(9.3)	(100.0)	**
Organophosphates	22	Malathion	1.3	1.1	0.7	1.9	0.8	0.8	5.3	12.0	89.0	2.9
Oxides, alkylene	23	Propylene oxide	0.8	0.8	0.4	1.1	0.7	0.7	5.2	8.7	79.0	4.6
Peroxides	24	alpha,alpha-Dimethyl-benzylhydroperoxide	1.1	1.1	0.8	1.7	0.9	1.0	10.5	11.3	93.0	1.6
Phenols & cresols	25	Cresol	1.3	1.1	0.8	2.0	0.9	0.9	**	12.3	100.0	5.6
Sulfates & sulfites	26	Dimethyl sulfate	1.3	1.4	0.6	2.3	1.1	1.0	6.3	10.4	112.0	2.1
Sulfides & mercaptans	27	Carbon disulfide	1.3	1.4	0.8	1.9	1.0	[1.0]	6.0	9.4	119.0	12.1

* The reported preference index data are unitless and were determined from sorption capacity data measured experimentally in the laboratory except as noted:
( ) = estimated value
[ ] = literature value

** = Preference index data are not reported for those sorbent/hazardous liquid pairs determined to be incompatible or non-wetting or for which no data exist (see Table 81).

LEGEND:

CLP = Cross-Linked Polymer	PP = Polypropylene
D = Diatomite	PU = Polyurethane
EM = Expanded Mineral	SC = Sorbent Clay
FC = Foamed Glass	TWF = Treated Wood Fiber
PE = Polyethylene	WF = Wood Fiber

sorbent. The preference index provides an indication of a sorbent's performance in a waterspill scenario. The larger the hazardous liquid/water preference index, the greater the hydrophobic quality of the sorbent and the greater the likelihood that it will preferentially sorb hazardous liquid instead of water in an aqueous medium.

Section C - "Technical/Logistical Information"

This section presents guidance on equipment and techniques to use for: 1) the application and collection of sorbents in a spill cleanup situation, 2) the immobilization by sorbents of hazardous liquids for disposal in a landfill, 3) reuse of sorbents, and 4) the disposal of used sorbents. The text describes equipment and manpower requirements, limitations, and safety precautions for the application and collection of the three basic sorbent forms: 1) particulate, 2) pillow, pad, or mat, and 3) sorbent booms.

Section D -"Cost Estimation Procedures And Data"

This section provides data for estimating the cost of using a sorbent. A discussion of general cost categories for cleanup with sorbents is presented. The major categories are equipment, expendable materials, labor, disposal, and transportation. Cost data are given in 1983 dollars for estimation purposes. Guide Sections B and C should be consulted to determine specific equipment, materials, labor, disposal, and transportation requirements.

Section E - "Test Methods"

Section E describes test methods available for evaluating sorbent performance characteristics such as sorption capacity and release rates. Brief descriptions of the test methods, including purpose, applicability, limitations, and data and resource requirements are provided. These sorbent test methods

are discussed in the Manual to enable selection of an appropriate test method if required. Manufacturers' data on sorption of hazardous liquids by sorbents generally do not cite test procedures. The absence of sorbent performance data derived from a common test method makes comparison of results difficult. The test methods cited were developed by the American Society for Testing and Materials (ASTM), General Services Administration (GSA), Westinghouse Corp., Rensselaer University, U.S. Coast Guard, Environment Canada, and Environmental Monitoring and Services, Inc. (Combustion Engineering).

Section F - "Spill Scenario Rationale"

Section F presents the rationale for selecting and defining the four cleanup scenarios considered in this Manual: 1) spills onto land, 2) floating spills into water, 3) non-floating spills into water, and 4) disposal in landfills. These scenarios represent situations where sorbents are likely to be a viable method of spill treatment.

Section G - "Sources of Information"

Sources of information on CERCLA liquids and sorbents are presented in Section G. References such as reports, handbooks, publications, and vendors are identified.

Section H - "CERCLA Liquid Chemical Information"

Section H presents physical property data on specific gravity, solubility in water, viscosity, and surface tension for the CERCLA liquids. The physical data tabulation enables identification of CERCLA liquids with similar physical properties, which is useful information for estimating sorption capacity for similar liquids. The hazardous liquid specific gravity, in conjunction with sorbent specific gravity and sorption capacity, can be used to calculate the

volume of loaded sorbent that will be generated and will subsequently require disposal. The data are organized alphabetically by chemical class followed by the hazardous liquid CERCLA name and the CAS Registry number.

CONCLUSIONS

A Guidance Manual for the Selection and Use of Sorbents for Liquid Hazardous Substance Releases, which is nearing completion, provides a concise compilation of information and data pertaining to the selection, acquisition, application, collection, regeneration, and disposal of sorbents. The inclusion of a chemical index (by chemical name and DOT number), which is cross-referenced to "Sorbent Selection and Use Guides" and "Sorbent Data Sheets," enables the user to quickly locate pertinent sorbent information for the liquid hazardous substances addressed in the Manual. The Manual includes 190 sorption capacity measurements that were made as part of the project and which were unavailable in the literature prior to this effort. The availability of a condensed source of information on sorbents promotes their efficient use by assisting decision-makers to estimate and compare the effectiveness and cost of various sorbent-use strategies. Although the primary target audience for the Manual is Federal On-Scene Coordinators and their technical support staffs, the Manual is also applicable to the needs of spill clean up managers representing State and local agencies as well as the private sector.

REFERENCES

Herrick, E.D., D. Carstea, and G. Goldgraben. Sorbent Materials for Cleanup of Hazardous Spills, EPA-600/2-82-030, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1982.